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METHOD AND APPARATUS FOR PRODUCING OZONE
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One aspect of the present invention concerns an apparatus for producing ozone from a gas containing molecular oxygen, which comprises;

two spaced apart concentric tubes of a dielectrical material between which the gas passes, the inner of said concentric tubes containing an electrode with a plurality of windings of a conductive wire electrode around its inner surface or a central rod inside its inner surface; the outer of said concentric tubes having a plurality of windings of a conducting wire electrode around its outer surface, both of said electrodes being connected to a high voltage AC electric current device,whereby the current flowing between the electrodes through the dielectric tubes and the passing gas converts at least some of the molecular oxygen to ozone.

Another aspect of the present invention concerns a method for producing ozone from a gas containing molecular oxygen which comprises; passing the gas between two concentric tubes of a dielectric material, the inner of said concentric tubes containing an electrode with a plurality of windings of a conductive wire electrode around its inner surface or a central rod inside its inner surface the outer of said concentric tubes having a plurality of windings of a conducting wire electrode around its outer surface,

both of said electrodes being connected to a high voltage AC electric current device, whereby the current flowing between the electrodes through the dielectric tubes and the passing gas converts at least some of the molecular oxygen to ozone

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COMPLETE SPECIFICATION

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Complete Specification for the invention entitled: METHOD AND APPARATUS FOR PRODUCING OZONE

The following statement is a full description of this invention, including the best method of performing it known to me:—*

* Note: The description is to be typed in double spacing, pica type face, in an area not exceeding 250 mm in depth and 160 mm in width, on tough white paper of good quality and it is to be inserted inside this form.

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The present invention concerns an apparatus and method for the production of ozone from a gas containing molecular oxygen. Ozone is an extremely strong oxidizing agent that has many uses such as a germicide, bactericide or a general antiseptic. A particular use of ozone, or ozonated air is in the purification of waste and wastewater, especially in the secondary or tertiary treatment of sewage. Ozone is also used in the chemical industry as an oxidizing agent.

There are several methods known for producing ozone from air by means of an electrical discharge. Oxygen, or a gas containing molecular oxygen, usually air, passes between two electrodes separated by a dielectric material and a space for the gas stream. However, in these prior art methods the cost of producing even low concentrations of ozone is very high due to the low efficiency of these known processes. The high cost of producing ozone tends to discourage large commercial and industrial use of it, especially in the purification of water or wastewater. The relatively low efficiency of existing apparatus for producing ozone leads to the consumption of large amounts of electricity to produce sufficient ozone for the desired use.

The existing apparatus exhibit their inefficiency by transfering much of their input energy to heat, and thus requiring expensive cooling systems as a result. The air discharge temperature of existing units can reach 300 C, when the cooling system fails, for example. It is therefore desirable to produce an efficient means of making

ozone that does not require cooling systems, and in which the discharge temperature of the air has been raised only minimally

Various apparatus have been used in the past to produce ozone. These devices generally have two electrodes separated by dielectric barriers and space for the gas flow containing molecular oxygen, through which a high voltage electrical discharge passes. Different arrangements of these integers are known, but a common arrangement is for the two electrodes to be in the shape of concentric tubes which allow the feed gas to flow through the annular gap between the two tubes, which are also surrounded and separated by a dielectric material, usually glass. The outer tube can be made of stainless steel while the inner electrode may comprise a thin metal layer deposited on the inside of the dielectric glass tube. Frequently, a commercial ozone generator will comprise a large number of these electrode pairs in order to produce sufficient ozone for the required purpose.

In the present invention, an improved method and apparatus has been discovered for producing ozone in an efficient, and less costly manner than previously known.

One aspect of the present invention concerns an apparatus for producing ozone from a gas containing molecular oxygen, which comprises;

two spaced apart concentric tubes of a dielectrical material between which the gas passes, the inner of said concentric tubes containing an electrode with a plurality of

windings of a conductive wire electrode around its inner surface or a central rod inside its inner surface, the outer of said concentric tubes having a plurality of windings of a conducting wire electrode around its outer surface, both of said electrodes being connected to a high voltage AC electric current device,whereby the current flowing between the electrodes through the dielectric tubes and the passing gas converts at least some of the molecular oxygen to ozone.

Another aspect of the present invention concerns a method for producing ozone from a gas containing molecular oxygen which comprises; passing the gas between two concentric tubes of a dielectric material, the inner of said concentric tubes containing an electrode with a plurality of windings of a conductive wire electrode around its inner surface or a central rod inside its inner surface the outer of said concentric tubes having a plurality of windings of a conducting wire electrode around its outer surface, both of said electrodes being connected to a high voltage AC electric current device, whereby the current flowing between the electrodes through the dielectric tubes and the passing gas converts at least some of the molecular oxygen to ozone

Preferably the apparatus described above is located within a casing having an inlet for the gas containing oxygen adjacent to, and at one end of, the annular passage between the two concentric tubes, and an outlet for discharging the gas containing ozone adjacent to, and at the other end of, the concentric tubes.

It is also preferred that the inlet is a nozzle for injecting a fast moving stream of gas through the annular passage between the concentric tubes.

Preferably the gas is air or oxygen. It is also preferred that the gas, or air, or oxygenis compressed and above atmospheric pressure, and it is also preferred that the gas is cooled, to a temperature which is below normal operating temperatures, particular room temperature ie 15 to 35 C. His also preferred that the gas or air or oxygen is dried to a dew point down to about - 60 C

Preferably the electrodes are stainless steel or aluminium or copper. It is most preferred that the inner and the outer electrode wire is stainless steel or aluminium steel of 0.1 to 5.0mm in diameter or flat wire.

Preferably adjacent windings of the wire around circumference of the outer tube are each 0.01 to 30mm apart. It is preferred that the number of windings along the tube is at least 200. For small units the number of windings is preferably at least 3, and for large units is preferably at least 300.

The voltage used to produce the ozone is most preferably between 7,000 to 60,000 volts. The frequency of the AC current will normally be 50 to 700 Hz.

The rate of ozone production in this apparatus will depend upon the rate of gas flow through the annular space between the pair of electrodes and dielectric cylinders, the applied voltage, the number of windings, the pitch of the winding spacing, the thickness of the dielectric layers, the thickness of the electric wire as well as the distance apart of the two electrodes, the frequency of the AC current and the moisture content of the applied air of ozone. Each of these factors can be adjusted to give the optimum ozone production.

The invention is now discussed in more detail, with reference to the drawings.

Figure 1 shows a cross-section of a portion of the apparatus for producing ozone, along its axis.

Figure 2 shows a perpendicular cross-section through the apparatus.

Figure 3 shows a large unit capable of containing several apparatus for producing ozone.

Figure 4 shows a perpendicular cross-section through a unit as in Figure 3.

In an example of the invention, which is not meant to be limiting, pressurised air is injected into the annular space between the concentric tubes through a nozzle. The

air passes between borosilicate glass dielectric tubes. The outer tube has stainless steel or aluminium wire wound around its circumference, with each loop in close proximity to the next. It is preferred to use 316 grade or 304L grade stainless steel wire, although other grades and types of wire can be used in place of these if desired. The distance between each stainless steel or aluminium winding is a function of the power supply utilised. The preferred spacing is between 0.1 and 30mm, with 0.1mm spacing producing the maximum ozone generation per meter of tube, up to the point of ozone destruction in the tube. This point of ozone destruction is generally a function of the air flow rate, as well as the tube length and the frequency of the applied AC current.

The inner glass tube is fixed along the axis of the outer cylinder, and supported so that its surface is equidistant apart from the outer tube, and not touching. The gap between the two tubes should be uniform. The centre of the inner tube is occupied by a single stainless steel rod in this example, although an aluminium or stainless steel winding is preferred AC current with a voltage between about 7,000 and 60 000 volts volts is applied to the outer windings, the current passing through the dielectric (glass) layers, the gas flow and to the inner rod electrode, to cause a corona to occur between the two dielectric glass layers. The air passing though the annular gap between the layers is introduced by a nozzle, ideally at a velocity so that the ozone produced passes out of the apparatus before any short-circuiting can occur, due to the conductivity of ozone.

The efficiency of this example is in the range of 35% to 60%, in terms of the oxygen transformed to ozone. In air, this means that 7% to 12% of is volume is converted to ozone, since approximately 20% of air is molecular oxygen.

The preferred air flow rate depends on a number of factors, including the size of the apparatus, the concentration of ozone required to be produced and the size and arrangement of the other integers which make up the apparatus. For example, if air is injected at a rate of 8 litres of air per minute into the ozone producing apparatus of the invention, there will be produced up to 4.2 [redacted] grams of ozone per hour, when measured at STP (standard temperature and pressure).

In the present example, the temperature rise in the air discharge is in the order of 2 or 3 C, which indicates the unit is operating very efficiently, especially when compared with prior art units. No cooling system is therefore necessary.

However, the efficiency of ozone production will also improve if the gas is cooled and has a low dew point before passing through the d[illegible]rge. If gas under high pressure is used, the compression process will normally raise the temperature of the gas. Therefore,ccoling can be applied to the gas either to reduce it to room temperature, or even below room temperature if necessary.

In the present example, the power consumption per kilogram of ozone has been measured to be between 3 0 and 10 0 kw hours, depending upon the air quality, when air is injected into the unit at 5 to 15 psi, (gauge).

Turning to the drawings, Figure 1 shows schematically an apparatus 1 for producing ozone from a gas, such as air, which contains molecular oxygen. Figure 1 shows a cross-sectional representation along the axis of the concentric cylinders whereas Figure 2 shows a perpendicular cross-section. The apparatus 1 comprises two spaced apart concentric tubes of a dielectric material 2 such as glass having an annular space 3 through which the gas or air can pass. Figure 1 shows the direction which the gas may flow. The inner of the concentric dielectric tubes contains an electrode 4. The outer of the concentric tubes 2 has a number of windings of a conducting wire electrode 5 around its outer surface, the wire being connected to a high voltage AC electric current supply. When the current is flowing, the silent electric discharge between the electrodes 4 and 5 through the gas in the passage 3 changes molecular oxygen into ozone.

The number of windings 5 of the outer electrode wire can vary, and so can the distance apart and pitch of each winding. As each cycle of AC current passes along the wire, causing each wire to form a corona between the windings and the central stainless steel rod 4, or windings similar to the outer windings and as the AC current normally oscillates at 50 cycles per second, the corona discharge created between

the electrode windings and the central core will give 100 rolling discharges per second. Thus an ozone producing apparatus in accordance with he invention with 50 or more windings will have an effectively continuous corona discharge between the two electrodes over the length of the windings. At AC frequency up to 700 cycles per second the efficiency of ozone production is increased 3 fold over 50 cycles per second.

Figure 3 is a representation of a unit designed to operate with 150 windings. The outer protective tube 10, has a diameter of 110mm and a length of 440mm. The tube 10 can house up to 7 separate ozone producing tubes. The end section of such an arrangement is shown in figure 4.

Figure 3 shows the unit 10 containing a single ozone producing unit. At each end of the unit is a centre electrode support 11. The outer electrode consists of stainless steel wire, 12, which has a diameter of 1mm. The outer diameter of the windings is 24mm. The inner electrode is a stainless steel 316 rod, 13, which has a diameter of 9.6mm. Surrounding the rod 13 is a borosilicate silicate glass tube 15, also with a wall thickness of 1.2mm, but with an inner diameter of 20mm. Supporting the unit is a PVC "Coronce" tube baffle and support plate 16. The air inlet 17 has a diameter of 4mm, as does the air outlet 18. The total diameter of the outer protective tube is 115mm, and the length is 440mm. In this example, the high voltage current is connected to the inner electrode, and outer electrode. The arrangement shown in

figures 3 and 4 is capable of producing up to 30 kg of ozone, per hour from an air feed and 84 kg/hour from an oxygen feed, both at a dew point of minus 40 C The desirable minus 40 to 50 C dew point is achieved by installing an air dryer between the air/oxygen supply and the unit. Alternatively instrument air or dry oxygen from a bottled source can be utilized.

It is also an advantage if the air or gas is cooled, since it is known that when dissolving ozone in water then the lower the temperature of the ozone then the higher the ozone concentration will become. Also, since cooler gas is more dense, then the greater density of cooler gas will assist the efficiency of the ozone production process.

This is particularly useful in using ozone to treat wastewater and to disinfect water supplies. Ozone has many advantages in the treatment of water, and is an eventually harmless additive, as unreacted ozone inevitably returns to the atmosphere as molecular oxygen. The dose rate of ozone to disinfect clean water may be as little as 0.1 to 0.2mg/litre, whereas heavily contaminated wastewater may require up to 30mg/litre to completely disinfect it. Therefore it can be seen that a cheap, effective method of producing ozone has great potential in water treatment, as well as in the previously known uses.

The present invention also concerns the apparatus and method referred to above whereby the production of ozone is monitored by the use of Ultra Violet LED (light

emitting diode) which emits light having a frequency of 253.7mm. Light of this frequency is reflected by ozone, and by measuring the light intensity at a distance form the LED and allowing the ozone containing air stream to pass between, then the concentration of ozone in that air stream can easily be calculated. With the present apparatus, it is preferred to place the unit as close as possible to the outlet from the ozone apparatus providing it is not within the light field from the corona discharge. The ozone measuring unit can be calibrated with standard chemical titration, such as that using potassium iodide as described in the standard reference text "Standard Methods", 16th edition.

It is preferred that the ozone apparatus be enclosed within a protective case as shown in Figures 3 and 4. The apparatus will be located in the case so that circulating air can cool the outer windings. The tubes will be held firmly within the casing. A preferred construction of the casing is to use uPVC pipe with glued on end caps; each end cap having the centrally located inlet or outlet. Preferably class 6 to 18 uPVC pipe can be used. The protective casing protects the ozone apparatus from damage in industrial use, and uPVC pipe is known to be suitable for use in ozone containing atmospheres and in use, it has been found that this material is not measurably degraded by the ozone. The uPVC also provides good electrical insulation to the ozone apparatus. A large number of units can be provided together in parallel to produce a greater supplier of zone if necessary.

The air supply to the apparatus of the invention would normally pass through a commercial moisture trap and dust filter to ensure that moisture or dust is not present to cause short-circuiting within the unit, and a consequent reduction of efficiency, thence an air dryer would be installed to achieve a dew point of minus 40 to 50 C

The apparatus of the present invention has been found to be highly economic in its production of ozone. A unit with 203 windings has a capacity to produce over ~~12 of~~ 12 ozone per hour. If additional ozone is required, then several such units can be arranged in parallel to produce multiples of this amount.

Units with more windings will produce proportionally more ozone, dependent upon the increase in air flow rate.

The above example and drawings are not meant to be limiting on the invention, and various modifications which are obvious to persons skilled in the art of the invention can be made to the invention without departing from its general scope.

DATED this ~~20th~~ 22nd day of February, 1991

<u>CLEARWATER ENGINEERING PTY LTD</u>

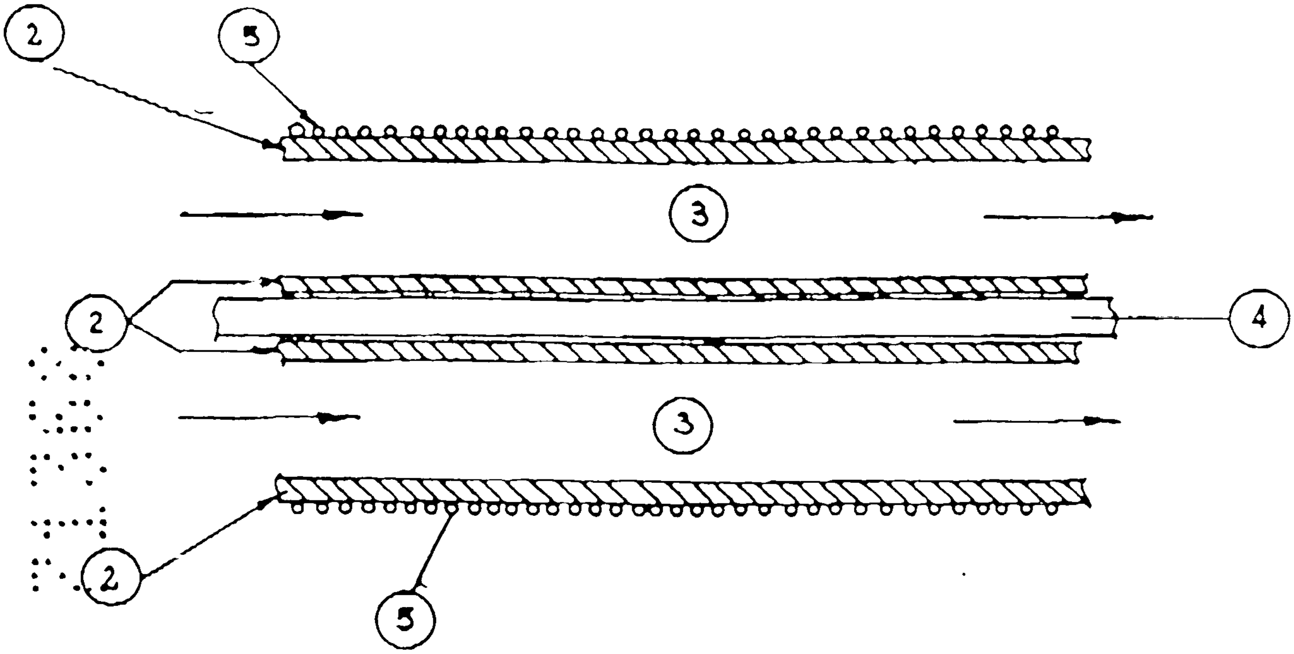

Figure 1

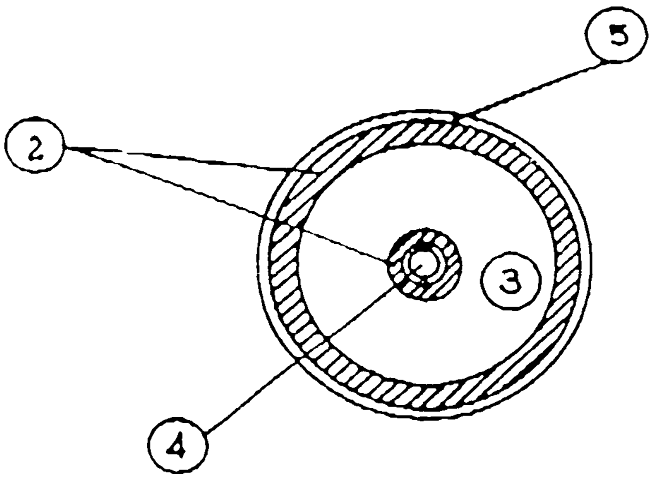

Figure 2

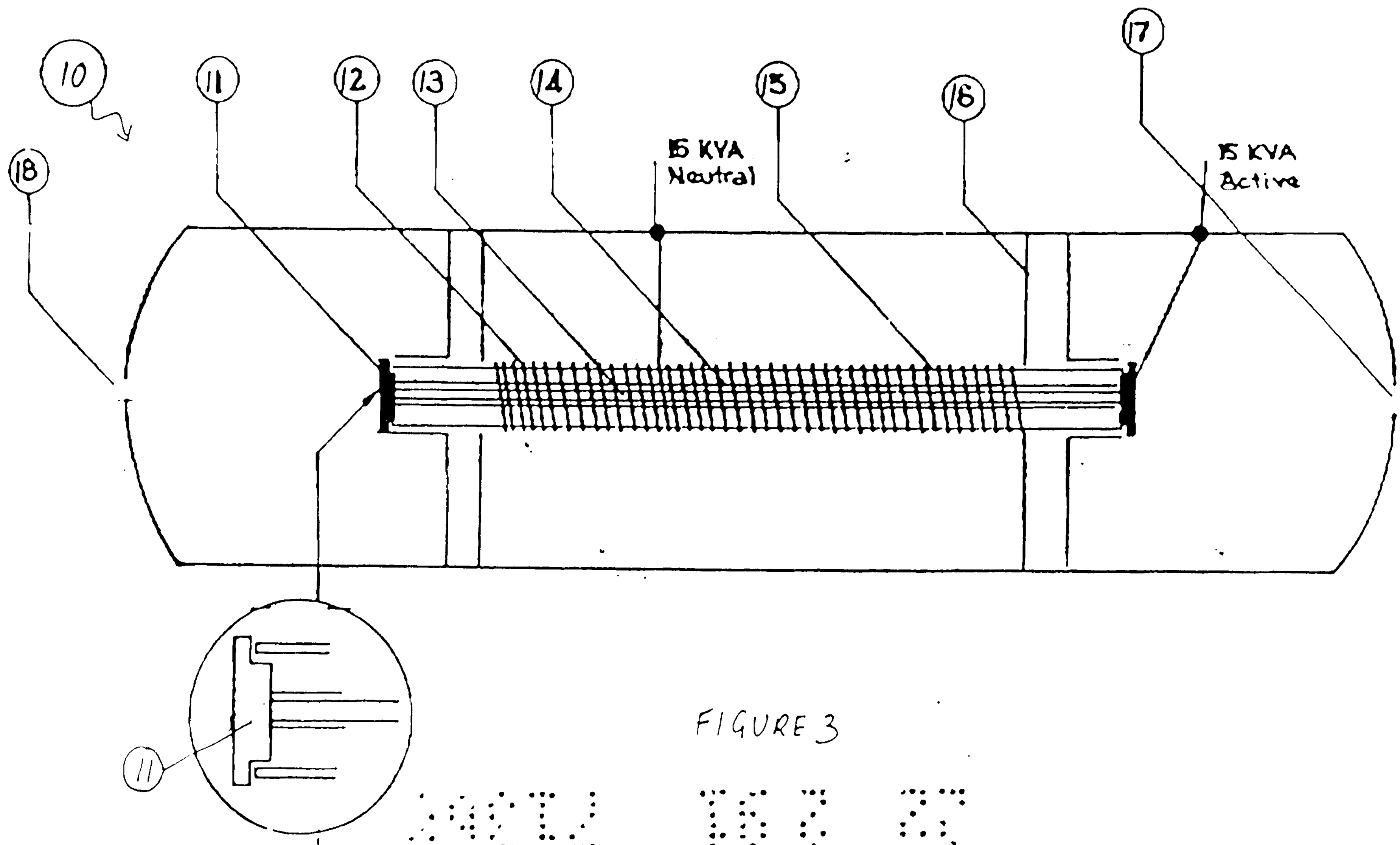

FIGURE 3

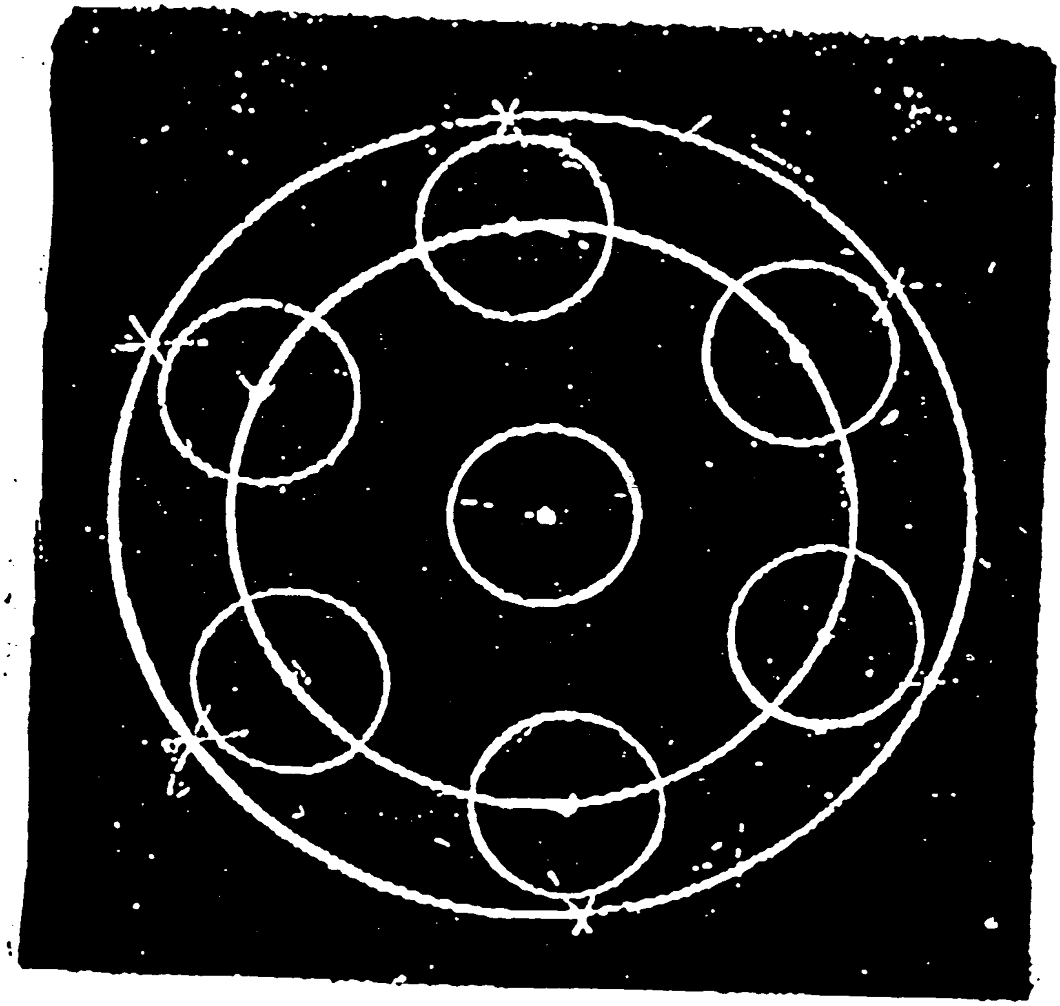

FIGURE 4